

APPLICATION OF CUSTOMIZED ABSORPTION HEAT PUMPS WITH HEATING CAPACITIES ABOVE 500 kW PROJECT: ACKERMANNBOGEN, MUNICH

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Abstract: A solar heating system was installed at “Ackermannbogen” in Munich, where a residential area was built in 2007. To achieve a solar fraction larger than 50%, a large seasonal storage was installed to store solar surplus during summer and supply solar thermal heat in winter. To decrease the needed volume of this storage an absorption heat pump was installed into the system. This heat pump utilises heat from the storage and is driven by heat from a district heating grid. The low temperature heat is lifted to temperatures useable within the local heating grid to provide heat and domestic hot water to the residential area. Due to the demand on temperature levels of the system a “twin” absorption heat pump - consisting of two separate absorption heat pumps within a single shell - had to be installed for this application. In order to gain maximum benefit of the stored solar thermal energy the system controls change the mode of operation depending on the temperatures of the storage and the return temperature of the solar thermal collectors. The system was monitored and the collected data (capacities and temperatures of the absorption heat pump) of a representative day is shown in this paper.

Key Words: solar heating, seasonal storage, twin absorption heat pump

1 INTRODUCTION

In 2007, apartment houses (320 flats; gross area about 30,000 m²) were built at the Ackermann Street (“Ackermannbogen”) in Munich. Heating of the apartments is realised by radiators and floor heating systems. To realise energy supply with a solar fraction higher than 50% large solar thermal systems (Σ 3,600 m², Figure 1) working with water-glycol supported by seasonal heat storage (5,700 m³) were installed. The seasonal heat storage uses water as medium and is a subsurface, insulated storage.



Figure 1: Picture of a building at Ackermannbogen showing a part of the solar system

A local heating grid, working with water, supplies the generated heat to the apartments. In order to maximise the utilisation of the seasonal heat storage an absorption heat pump (thermally driven heat pump, TDHP) was installed into the system. This TDHP is driven by district hot water and lifts low temperature heat of the storage to temperatures useable for heating purposes and is therefore increasing the energy storage density of the system. The district hot water is used as backup system e.g. due to system breakdown, too. A scheme of the system is shown in Figure 2.

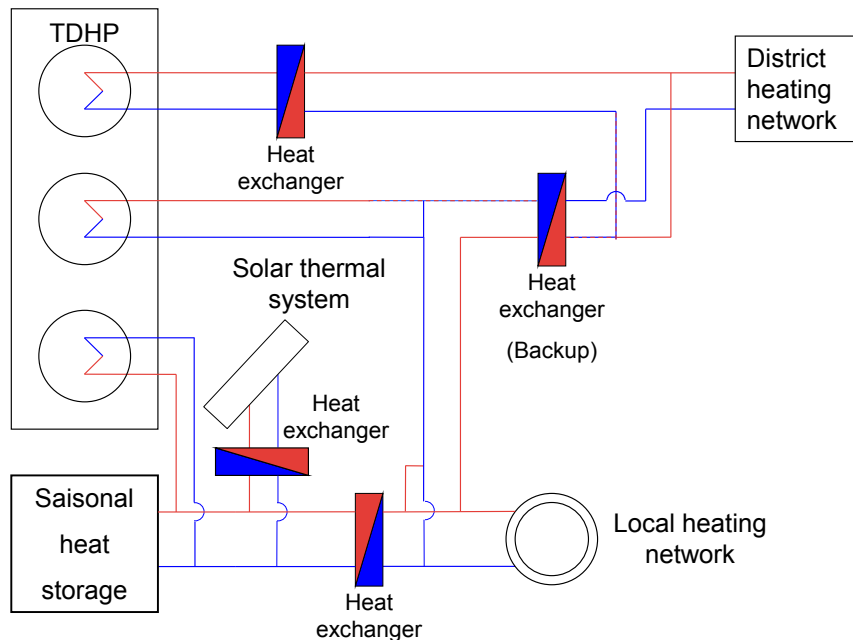


Figure 2: Simplified presentation of the system at Ackermannbogen

2 THERMALLY DRIVEN HEAT PUMP

The plant used at Ackermannbogen is a “twin” absorption heat pump, which is made of two separate heat pumps within a single shell. The external cycles pass serially through the individual components as shown in Figure 3.

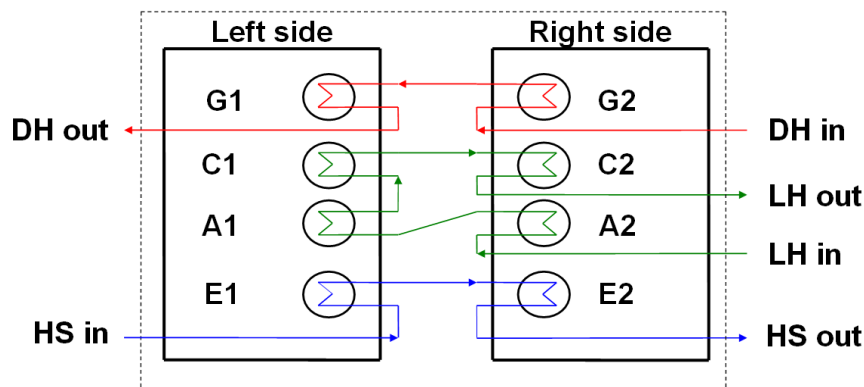


Figure 3: Scheme of the “Twin” TDHP and the external cycles

In this figure the main components of the heat pumps (generator G, condenser C, absorber A and evaporator E) are numbered to distinguish between the two plants. The absorption heat pump (4.6 m x 2.2 m x 3.2 m) is driven by hot water from the district heating network (driving

heat, DH). Depending on the ambient temperature the temperature of the district hot water ranges from 85°C up to 115°C. Low temperature source (heat source, HS) is the seasonal heat storage which is loaded by the solar thermal system. In nominal operation about 230 kW of low temperature heat are drained from the storage. The inlet temperature of the heat source varies between 33-12°C. Nominal heating capacity (local heat, LH) of the heat pump is about 550 kW with in- and outlet temperatures of 30/56°C. Figure 4 shows a picture of the plant.



Figure 4: Picture of the absorption heat pump at Ackermannbogen

The specification of the TDHP, as supplied by the manufacturer (Thermax Ltd.) is shown in Table 1.

Table 1: Specification (nominal operation) of the absorption heat pump

| Chilling capacity | Driving heat (district hot water) | | | Local heat (residential heating) | | | Heat source (storage heat) | | |
|-------------------|--------------------------------------|--------------|-------------------|-------------------------------------|--------------|-------------------|-------------------------------|--------------|-------------------|
| | Inlet temp. | Outlet temp. | flow | Inlet temp. | Outlet temp. | flow | Inlet temp. | Outlet temp. | flow |
| kW | °C | °C | m ³ /h | °C | °C | m ³ /h | °C | °C | m ³ /h |
| 230 | 115 | 85,8 | 9,5 | 30 | 56,2 | 18 | 22,2 | 10 | 16,21 |

As shown in Table 1 the temperature spreading of the external circles during nominal conditions is large, especially for the local heat grid. This is the main reason to use a twin absorption heat pump. Figure 5 shows the internal and external temperatures in a Dühring plot as expected at nominal load and temperatures. This diagram shows the vapour-liquid-equilibrium states of water and aqueous lithium bromide solution, which is the working pair the THDP uses for its process, as grey lines.

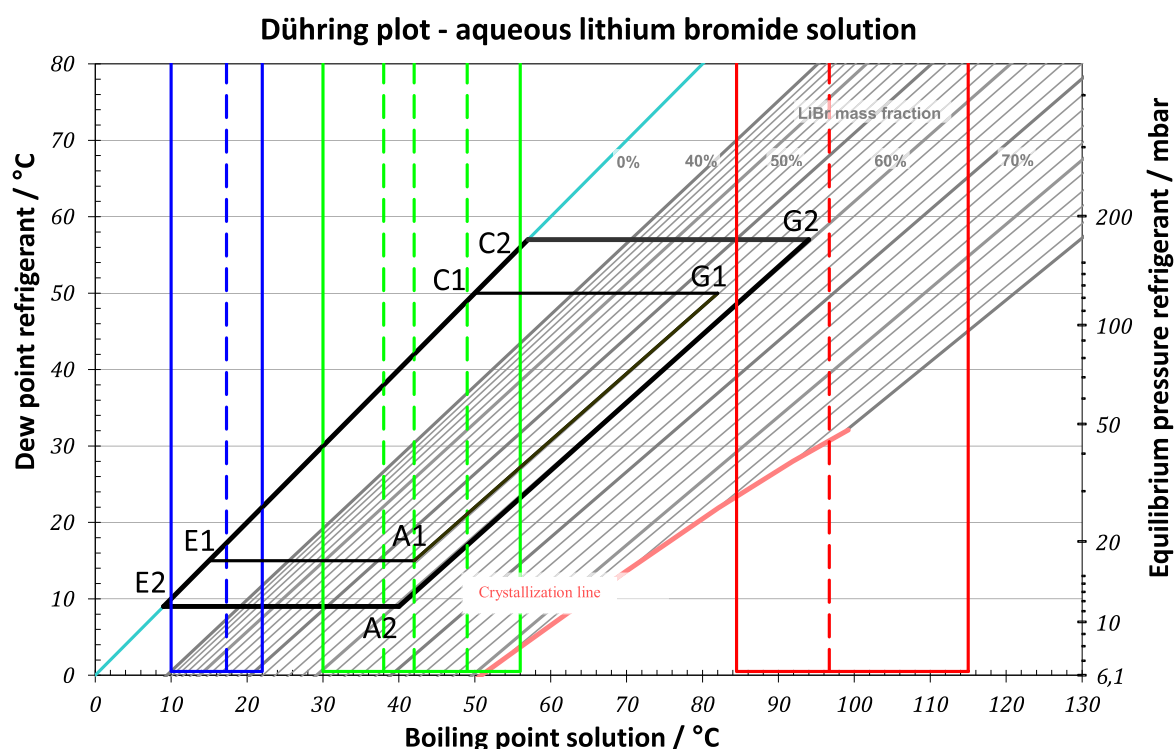


Figure 5: Operating conditions of the absorption heat pump

The thin and bold black lines show the internal state changes of the left and right part of the heat pump, as shown in Figure 5. The change in mass fraction from generator to absorber is neglected in this plot. The coloured upright lines show the temperatures of the external cycles. Dashed lines indicate external temperatures between the different components. It can be seen, a simple single effect absorption heat pump cannot be operated at the demanded external conditions. During winter the stored solar heat is used for space heating and domestic hot water preparation. As soon as the temperature of the storage drops below a certain set point the thermally driven heat pump utilises low temperature heat from the seasonal heat storage. The district heating grid provides additional heat as required.

3 CONTROL STRATEGY

During summer solar heat is used for domestic hot water preparation, the seasonal storage is charged with solar surplus. The heat pump is not in operation during summer time.

There are different operation modes to control the whole system. The system switches automatically between different modes, depending on temperature conditions as shown in Table 2.

Table 2: Operation modes of the system

| Mode | Explanation | Required condition |
|------|-------------------------------------|--|
| BA 1 | District heat only | Supplied temperature to residential buildings < 55°C |
| BA 2 | Storage/ Direct solar | storage Temperature > 65°C Temperature solar > 65°C |
| BA 3 | Storage with district heat | storage Temperature < 65°C |
| BA 4 | Storage with TDHP and district heat | storage Temperature < 40°C |
| BA 5 | TDHP with district heat | storage Temperature < 33°C |

Mode BA1 is used as backup only. In case of system failure, maintenance of the system or periods when solar thermal energy (from solar radiation or storage) is not available this mode ensures supply of heat to the housing area.

If the temperature supplied by either the seasonal heat storage or the solar thermal system is higher than 65°C, the heating energy can be provided by the heat storage or the solar thermal system directly. Therefore in Mode BA2 heat for the residential buildings is supplied directly by the storage or the solar system.

As the storage temperature drops below 65°C, the system switches to Mode BA3. During BA3 warm storage water is used to preheat the return of the residential heating, while the district heating maintains the inlet temperature for the residential buildings at an appropriate level.

If the storage temperature drops below 40°C the THDP starts operating. After the preheating by the storage, the THDP lifts heat from additional storage water to further increase temperature of the residential building return. Afterwards, equivalent to mode BA3, the district heating controls the inlet temperature for the residential buildings.

When the storage temperature drops below 33°C, the system switches to mode BA5. The operation is similar to mode BA4, without the preheating by the storage heat.

Any solar heat surplus is stored in the seasonal storage. Due to the temperatures of the storage and the solar system and the low heating demand, the heat pump is not in operation during summer time.

The municipal utilities demand a return temperature of the district hot water below 50°C. Therefore after driving the heat pump the district hot water exchanges heat with the local heating grid. This means even though the heat pump, driven by district hot water, could fully supply the residential area with heat and domestic hot water, an additional fraction of the heat demand has to be provided by the district heating grid.

4 MEASURED DATA

Measured data of the 8th February 2012 will be discussed. Table 3 shows the calculated transferred heat of the system at this day.

Table 3: Measured heat converted by the absorption heat pump on the 8th of February 2012

| | | |
|---|-----|------|
| Driving heat | kWh | 5940 |
| Local heat supplied by heat pump | kWh | 9280 |
| Heat source TDHP | kWh | 3250 |
| COP | - | 1.56 |
| Local heat supplied directly by district heat | kWh | 4050 |

It can be seen that only about a quarter of the thermal energy demand is supplied by the solar energy from the storage (heat source THDP). The small solar fraction is caused by the forced heat input from the district hot water to the local heating grid as described above.

Figures 6 and 7 show the capacities and temperatures at the heat pump and the local heating network.

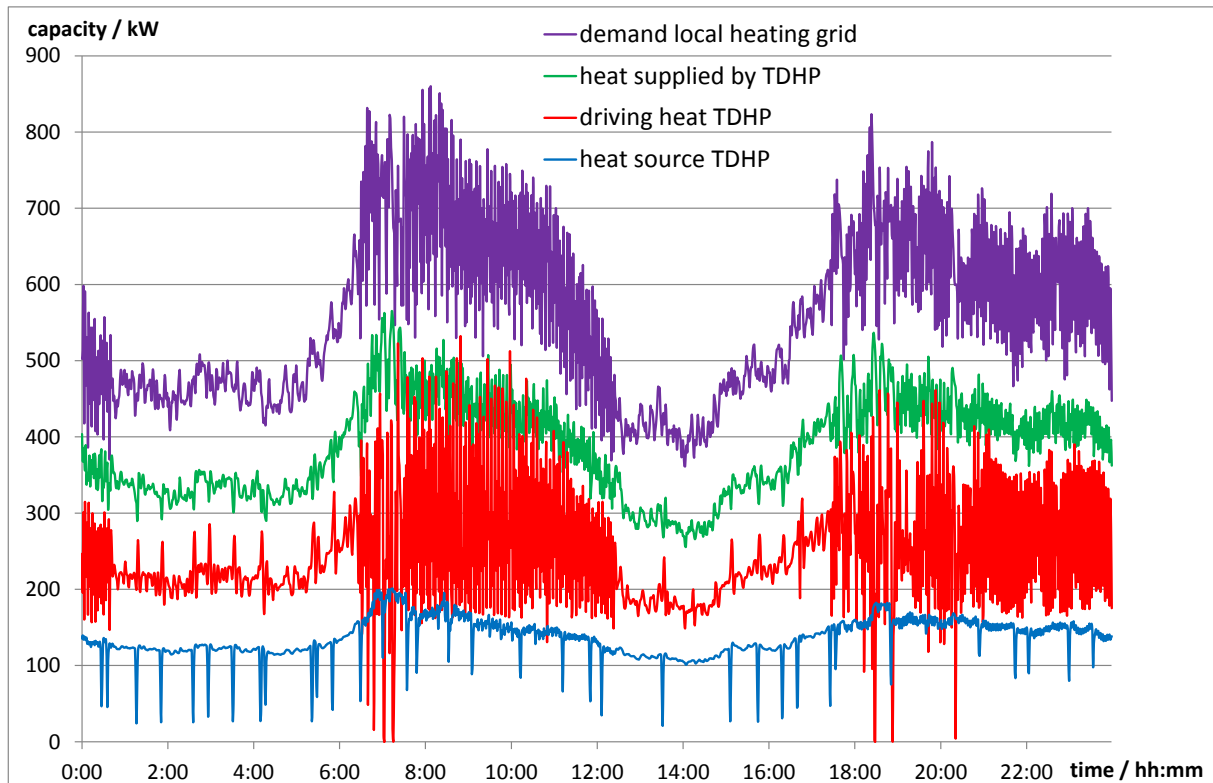


Figure 6: Capacities measured at the TDHP on the 8th Feb 2012

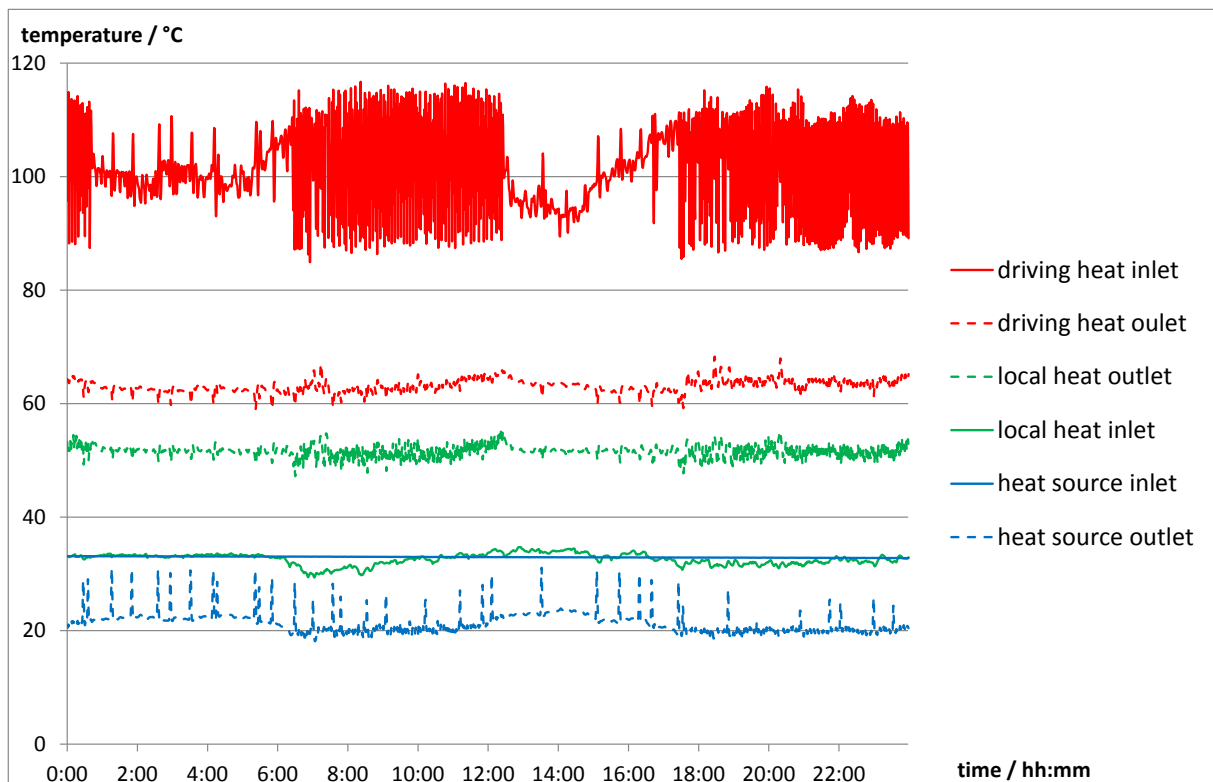


Figure 7: Temperatures measured at the TDHP on the 8th Feb 2012

In Figure 6 the increase of the heating load at morning and evening, the fluctuation of the heat load and the difference between heat demand and useful heat supplied by the heat pump can be seen. The fluctuation of the driving heat capacity is directly caused by the

controls trying to compensate the change of heat load. As the heat pump has a high thermal mass the heat provided to the local grid is more stable. The negative peaks of the heat source capacity are caused by the temperatures at the heat pump which are shown in Figure 7.

As this diagram indicates the temperature supplied by the storage (heat source inlet) and the return temperature of the local heating grid (local heat inlet) at this day have been nearly similar. This caused a very low lithium bromide concentration in the absorber and therefore a low level in the evaporator. The peaks in heat source outlet temperature occur when the level in the evaporator drops below the minimum set point and the internal refrigerant pump stops working to prevent cavitation.

The strong fluctuation in hot water inlet temperature is caused by the controls as the amount of district heating water supplied to the heat pump is controlled with respect to the temperature of the local heating net inlet and the pump circulating the hot water of the heat pump with respect to the outlet temperature of the district heating water. Due to this coupling the fluctuation of the local heating grid can be seen in hot water inlet temperature.

Especially Figure 6 shows an operation of the heat pump at about 300-450 kW heating capacity. Usually the heat pump is not working at more than 30 % part load due to an overestimation of the heat demand of the residential area during the system design. The continuous operation in small part load and the temperatures supplied by the system (causing the refrigerant pump to stop regularly) are the main reasons of the resulting COP of only about 1.55.

5 CONCLUSION

At “Ackermannbogen” in Munich a thermally driven “twin” heat pump has been installed to lift low temperature heat of a seasonal storage to temperatures useable for heating and providing hot water for a residual area. Due to the temperatures provided to the heat pump and the oversize of the heat pump it operates in small part load only, therefore not reaching its nominal COP.

This project has shown a TDHP can be used to increase the energy storage density of a seasonal storage by decreasing the lowest temperature utilisable. This combination of systems can therefore be useful to reach high solar fractions ($\geq 50\%$). At such complex systems the main issues to take care, besides the design of the main components and their implementation, are the controls and the correct sizing of the whole plant.

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